U-PB AGES OF LUNAR APATITES. J. Vaughan[1], A.A. Nemchin[1], R.T. Pidgeon[2] and C. Meyer[3], [1]Western Australian School of Mines, Curtin University of Technology, Bentley Western Australia, 6102, Australia. [2]Department of Applied Geology, Curtin University of Technology, Bentley, Western Australia, 6102, Australia. [3]NASA Johnson Space Center, Houston, Texas, USA.

Introduction: Apatite is one of the minerals that is rarely utilized in U-Pb geochronology, compared to some other U-rich accessory phases. Relatively low U concentration, commonly high proportion of common Pb and low closure temperature of U-Pb system of apatite inhibit its application as geochronological tool when other minerals such as zircon are widely available. However, zircon appear to be restricted to certain type of lunar rocks, carrying so called KREEP signature, whereas apatite (and whitlockite) is a common accessory mineral in the lunar samples. Therefore, utilizing apatite for lunar chronology may increase the pool of rocks that are available for U-Pb dating. The low stability of U-Pb systematics of apatite may also result in the resetting of the system during meteoritic bombardment, in which case apatite may provide an additional tool for the study of the impact history of the Moon. In order to investigate these possibilities, we have analysed apatites and zircons from two breccia samples collected during the Apollo 14 mission. Both samples were collected within the Fra Mauro formation, which is interpreted as a material ejected during the impact that formed the Imbrium Basin.

Samples: Sample 14306 is classified as a crystalline matrix breccia (Simonds et al., [1]), consisting of three fragment generations. The oldest fragments are coarsely crystalline and partly glassy basaltic (noritic) microbreccias, the second generation are dark grey micro- to cryptocrystalline polymict microbreccias and the third generation is the matrix, similar in composition to the second generation fragments (Anderson et al., [2]). Polished thin section 14306-60 contains fragments and matrix material that are consistent with the above descriptions. All of the apatite and zircon grains dated in this sample are contained within one large fragment (5x4 mm) of noritic gabbro microbreccia. This large fragment contains coarse-grained aggregates and broken crystal fragments (up to 1 mm) of plagioclase and pyroxene set in a dark glassy matrix. The large fragment also contains numerous apatite, zircon and ilmenite grains ranging in size up to 0.7 mm for the largest apatite and 0.4 mm for the largest zircon (both of which are part of coarse-grained gabbroic aggregates). Apatite and zircon grains vary from euhedral crystals in aggregates to broken fragments in the matrix.

Sample 14066 is classified as a crystalline matrix breccia (Simonds et al., [1]) with medium grey lithic fragments in a pale grey matrix. Polished thin section 14066-47 consists of subhedral to euhedral single crystals and broken fragments of plagioclase and pyroxene (up to 1.4 mm) together with a few rounded, darker grey, fine-grained lithic fragments (up to 1 mm) set in a fine-grained, pale grey, plagioclase-rich matrix. Some of the rounded lithic fragments are surrounded by narrow, highly birefringent reaction rims. The section contains numerous grains of apatite, zircon and ilmenite disseminated through the fine-grained matrix. The largest apatite grain is about 100μm and the largest zircon grain is about 200 μm in diameter. However, most of these grains are 10 to 20 μm in diameter, and only a few were large enough for ion microprobe analysis.

Analytical technique: Polished thin sections of samples 14306-60 and 14066-47 were systematically searched using SEM/EDS to locate grains of apatite, zircon, ilmenite and other accessory minerals, which were identified using a combination of BE grey-scale images and semi-quantitative EDS analysis. U-Pb analyses on zircons and apatites were made using the Western Australian consortium SHRIMP II at Curtin University of Technology. Zircon grains were analysed using procedure described by Compston et al. [3] and Kennedy and de Laeter [4]. U/Pb ratios were calibrated against the Sri-Lankan zircon CZ3 (Pidgeon et al. [5]). Analyses of apatite followed similar protocol, but integration times have been increased 3-4 times for Pb and U isotopes in order to increase total number of collected counts. A large apatite crystal from Brasil with the age of **2023 Ma and U concentration of 60 ppm** was used as the standard during the analyses.

Results: Analyses of seven zircon grains from the sample 14306 show uniform U (range 26-44 ppm) and Th (range 16-30 ppm) concentrations and $^{206}Pb/^{204}Pb$ varying between ~300 and 7000. These seven analyses are all concordant (Fig. 1) within the errors and determine an age of 4202±7 Ma (95% confidence)

Three out of five zircon grains from the sample 14066 have significantly higher U and Th concentrations (137-304 ppm and 70-171 ppm respectively). All analyses also show higher proportion of radiogenic Pb ($^{206}Pb/^{204}Pb$ varying from ~500 to 11000). Analyses are slightly reverse discordant (Fig. 1) and do not form a single age population. Three of these zircons determine an age of 4158±12 Ma (95% confidence), whereas other two are older ($^{207}Pb/^{206}Pb$ ages are 4225±18 Ma (2σ) and 4352± 6 Ma)
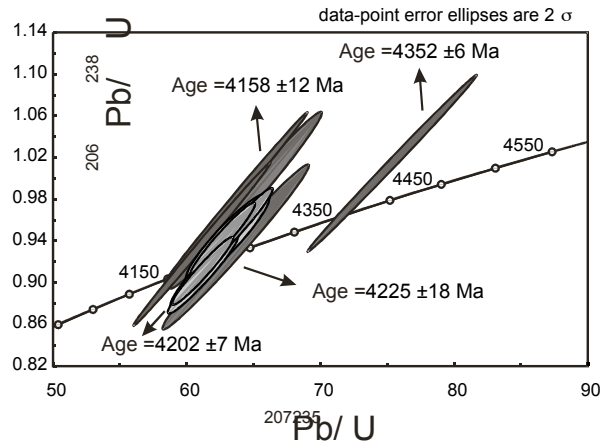
Figure 1. U-Pb analyses of zircon grains from the samples 14306 (light grey) and 14066 (dark grey).

Concentrations of U in the apatite grains from the sample 14306 are very similar to that of zircon analysed in this sample and vary between 18 and 36 ppm, However, Th content is significantly higher (~420-575 ppm) and $^{206}Pb/^{204}Pb$ ratios significantly lower varying between ~70 and 600.

Th concentrations in apatites from the sample 14066 also scatter around ~500 ppm, similar to the apatite from the sample 14306. However, U content in 14066 apatites is significantly higher similar to that of zircon from the same sample. This relatively high U content results in higher proportion of radiogenic Pb ($^{206}Pb/^{204}Pb$ ratios between ~900 and 9000).

Relatively large proportion of ^{204}Pb especially in apatites from the sample 14306 rases an issue of applying accurate correction for initial Pb, as this increased ^{204}Pb proportion either suggests that the initial Pb is close to that usually observed in terrestrial samples or surface of analysed samples is contaminated with the terrestrial lead. The first explanation contradicts a common beief that the Moon lost its Pb very early in the history, whereas the second is not adequately supported by analyses zircons and apatites from the same samples, showing similar U concentrations, but very different $^{206}Pb/^{204}Pb$ ratios, even though there is difference between the ages of zircons and apatites and zircons are expected to accumulate larger quantities of radiogenic Pb. This second possibility is also not fully supported by the observed lack of change in $^{206}Pb/^{204}Pb$ ratios during the run, correlated with the depth of an analytical pit. It is possible, therefore, that the non-insitu produced component of Pb in analysed apatites is represented by a mixture of more radiogenic initial Pb and more common Pb representing surface contamination. This issue cannot be completely re-

solved with the currently available data. Therefore, the best available option for estimation of ages of analysed apatites is to constrain an isochron through uncorrected data, assuming that the proportion of two components in non-insitu produced Pb does not change significantly. If this approach is used, intercept of a line fit through all analyses obtained for the sample 14306 in 3D ($^{204}Pb/^{2064}Pb-^{207}Pb/^{206}Pb-^{238}U/^{204}Pb$) coordinate system (Fig. 2) determines an age of 3905±69 Ma. The intercept of similar line constrained on the basis of analyses made for apatites from the sample 14066 defines similar but more precise age of 3917±19 Ma.
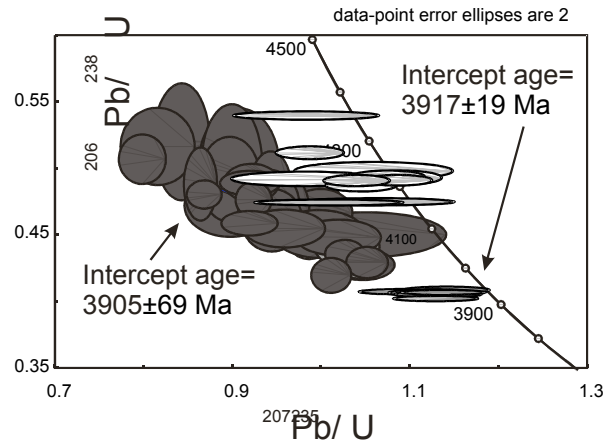

Figure 2. Common Pb uncorrected U-Pb analyses of apatite grains from the samples 14306 (dark grey) and 14066 (light grey). Zircon data from both samples (white) are shown for comparison.

Discussion: It is evident from the obtained analyses that the zircon grains in both samples preserve their original ages, while the U-Pb systems of apatites are reset. Sample 14306, where both zircons and apatites were analysed in a single clast of noritic-gabbro shows a single population of zircon ages with an average of 4202±7 Ma, which can be considered as an age of the noritic-gabbro. Both zircons and apatites in the sample 14066 are distributed within the breccia matrix and difference in zircon ages probably reflects sampling of different rocks mixed in the breccia. Nevertheless, apatites in both samples show similar ages of about 3.9 Ga, which must reflect Imbrium impact, as both samples are collected from the Fra Mauro formation interpreted as ejecta formed during this impact.

References: [1] Simonds et al. (1977) [2] Anderson et al. (1972) [3] W. Compston et al. (1984) *JGR, 89,* 525-534. [4] A.K. Kennedy and J.R. de Laeter (1994). *8th ICOG,* Abstract, 166. [5] R.T. Pidgeon et al. Laeter (1994). *8th ICOG,* Abstract, 251.